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SUPINATION-ADDUCTION INJURIES OF THE ANKLE IN CHILDREN - RADIOGRAPHICAL CLASSIFICATION AND TREATMENT

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ABSTRACT

Diagnostical and therapeutical problems associated with supination-adduction injuries are presented. 457 ankle fractures were collected from a retrospective material of 919 children aged 0-18 years with fractures of the tibio-fibular shaft or the ankle. The ankle fractures were classified anatomically according to Salter and Harris and traumalogically according to Gerner-Smidt. 147 fractures were classified as due to supination-adduction, of which 128 had open growth plates.

The first stage, a Salter-Harris type I, II, or III fracture through the lateral malleolus or only epiphyseal fracture without fracture through the growth plate, is easily overlooked and is probably more common than earlier registered.

The stage II injury with, in addition, a vertical or oblique fracture of the medial malleolus sometimes continuing through the physis and metaphysis is often more easily recognized at the radiographical examination.

The mean age of supination-adduction injuries is lower than for supination-eversion injuries. The supination-adduction injuries are the second most common type of ankle fractures in children (32%) only exceeded by injuries due to supination-eversion (39%).

Early recognition of the fracture pattern of supination-adduction injuries is important as growth disturbance and joint problems are not uncommon when there is fracture through the medial malleolus. The need for correct diagnosis and treatment is stressed by the risk for late problems.

INTRODUCTION

Poland (1898) described a thickening and a bowing of the fibula accompanied by a small internal malleolus besides shortening of the bone as the remaining deformity after an adduction injury earlier described by Ollier (1881). Later, McFarland (1931) described another fracture through the medial malleolus caused by adduction that resulted in a varus deformity due to growth arrest at the medial part of the growth plate.

The mechanism of trauma was further considered by Bishop (1932) and Carothers and Crenshaw (1955) who separated three degrees or stages of adduction injuries. These injuries have also been classified as supination injuries (Ehalt 1961, Titze 1967) which include supination-adduction.

Experimentally, Gerner-Smidt (1963) produced three types of supination injuries: supination-eversion, supination-adduction, and supination-inversion. Two stages of supination-adduction (SA) were identified: first stage - fracture through the growth plate of the distal fibula, second stage - in addition a fracture through the medial malleolus. Transverse or oblique fracture of the distal fibular epiphysis and/or ligamentous injuries at the tip of the lateral malleolus were classified as alternative or associated injuries to the first stage and ligamentous injuries at the medial malleolus were classified as a rare associated injury to the second stage. The third degree injury, according to Ashhurst and Bromer (1922) and Bishop (1932), were excluded. This injury was not produced experimentally and was not supposed to be due to a bending force, but compression along the bone with the ankle in a position of adduction (Gerner-Smidt, 1963).

Knowledge of the traumatology and the anatomy of ankle fractures in children facilitates the recognition and treatment of these injuries. In this study, the fracture anatomy, and age and sex distribution of SA injuries have been evaluated from a retrospective material.

MATERIAL AND METHOD

919 fractures of the ankle and/or tibio-fibular shaft in 903 children aged 0-18 years were traced using the diagnose code registered (Ekenstam et al. 1976). The patients were diagnosed at the Department of Orthopaedics, Lund University Hospital, during the years 1971-1979.

457 ankle fractures in 453 patients were found. 361 children with 363 ankle fractures had open growth plates.

Traumatologically, the ankle fractures of child pattern were classified according to Gerner-Smidt (1963). Injuries of adult type were classified according to Lauge-Hansen (1942, 1950, 1953). Anatomically the fractures were classified according to Salter and Harris (1963).

RESULTS

128 injuries (128 cases) with open growth plates (Table 1) and 19 injuries (19 cases) with closed growth plates were classified as due to supination-adduction.

I. Radiography and treatment.

A. Open growth plates (Fig. 1)

Stage I

Physeal fracture

According to Gerner-Smidt stage I.

According to Salter-Harris

distal fibula: type I, II, or III,

distal tibia: no injury.

38 boys aged 1-16 years; 31 girls aged 3-17 years.

Forty-four cases had a S-H type I injury, 15 a S-H type II injury, and 10 S-H type III injury.

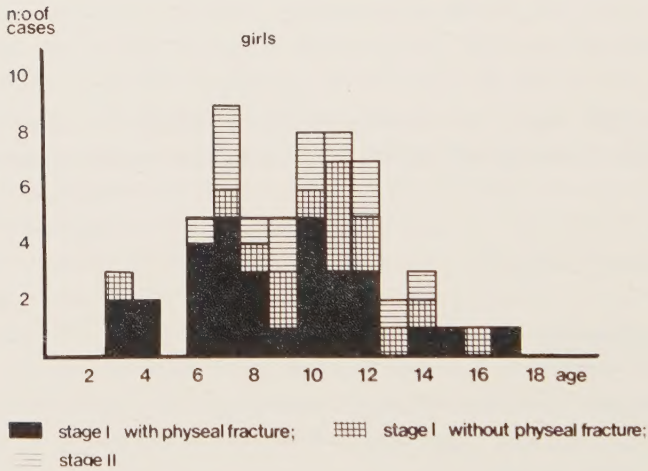
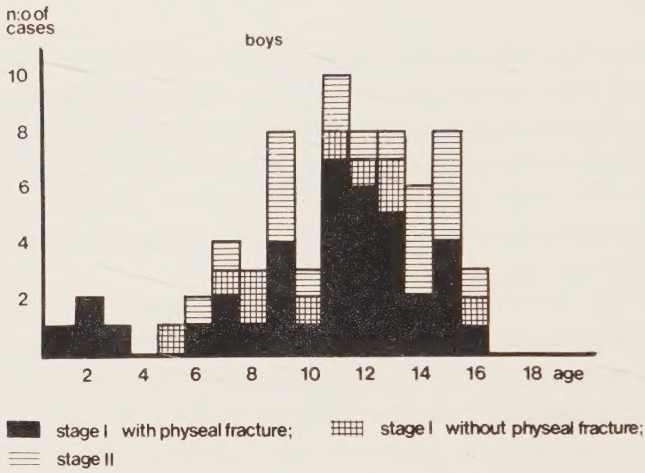


Table 1. Distribution of boys and girls with SA injuries and open growth plates.

The metaphyseal or epiphyseal fragment in the S-H type II and III injuries was always small (height up to 3 mm), and sometimes present only as a minimal fragment or a small sliver-like cortical avulsion from the metaphysis or the epiphysis. The exact position of the metaphyseal or epiphyseal fragment could not always be determined, but it could be situated both laterally or medially; more seldom anteriorly.

The type I injuries were revealed by a slight displacement (up to 3-4 mm); the tip of the lateral malleolus had moved medially, and a widening of the growth plate laterally was found (Fig. 2 a and b).

In three cases, radiographs at injury showed no signs of physeal fracture; three weeks later a thin periosteal callus was found close to the metaphysis (Fig. 3 a and b).

Two cases showed, in addition to the physeal fracture, a minimal fragment at the tip of the lateral malleolus.

Treatment: Plaster fixation was performed for on average 2-4 weeks depending on age.

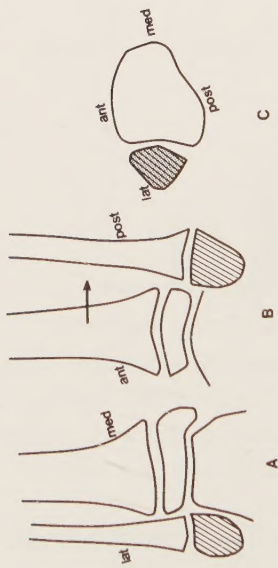
Epiphyseal fracture

According to Gerner-Smidt stage I.

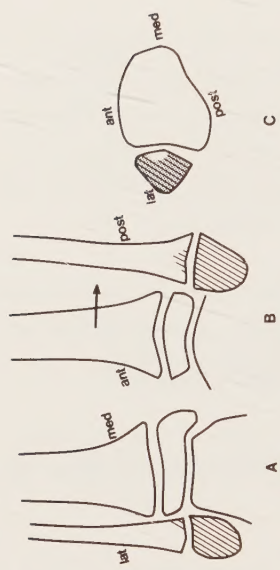
10 boys aged 5-16 years; 15 girls aged 3-16 years.

Fracture of the distal fibular epiphysis was usually found as a curve-shaped fracture 2-4 mm proximal to the tip of the lateral malleolus (Fig. 4 a and b). When the fracture was situated more proximal, it usually became more transverse. In a few cases the fracture was slightly asymmetrical and separated mainly the distal postero-medial part of the fibular epiphysis. The displacement was always small (up to 3 mm).

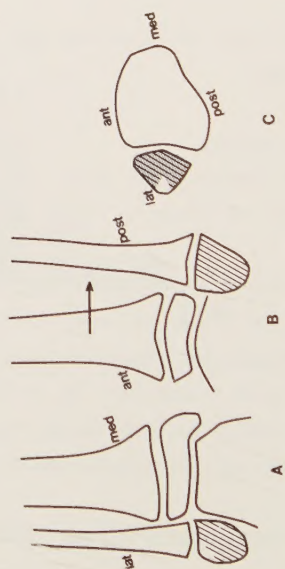
Treatment: Plaster fixation was performed for on average 2-4 weeks depending on age.



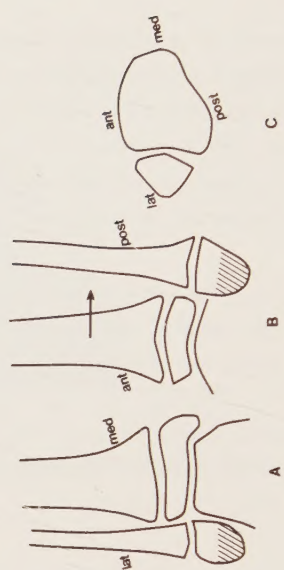
stage I - physal fracture
distal fibula: Salter-Harris I



stage I - physal fracture
distal fibula: Salter-Harris II



stage I - physal fracture
distal fibula: Salter-Harris I



stage I - epiphyseal fracture

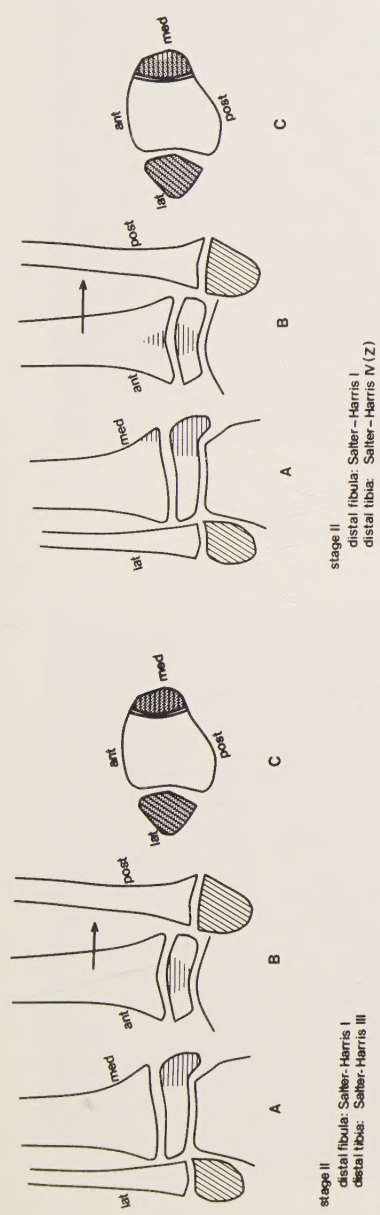


Fig. 1 Schematic drawings show different stages and types of SA injuries in children with open growth plates.

A - AP.
 B - Lateral. Fibula is illustrated to the right of tibia.
 C - Section through the growth plate of distal tibia and fibula, respectively.

- different fracture
 - fragments of distal tibia
- different fracture
 - fragments of distal fibula
- separation through growth plate of distal tibia and/or fibula

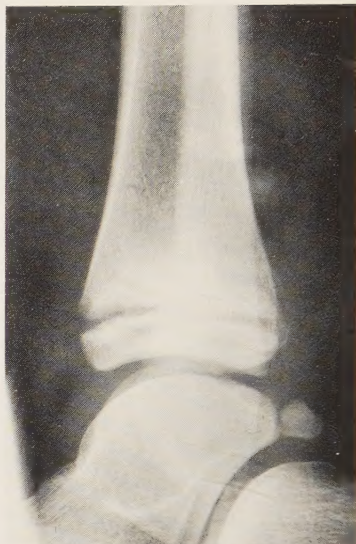
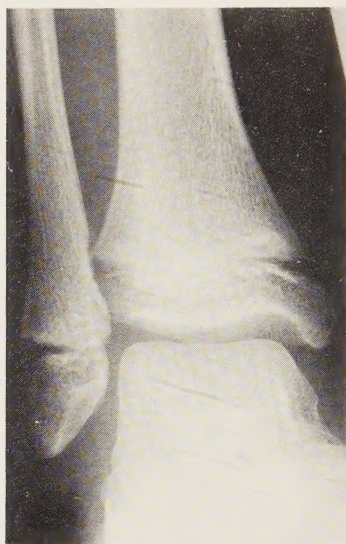


Fig. 2 Stage I - physeal fracture distal fibula.

a - AP. Widening of the distal fibular physis laterally.

b - Lateral.

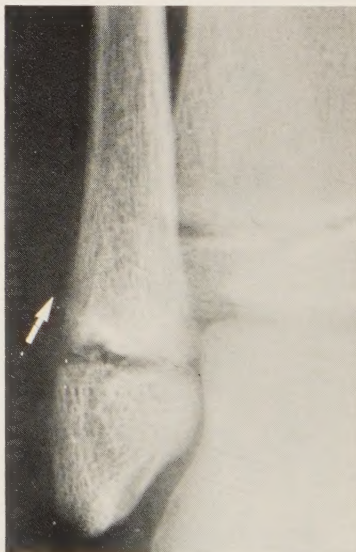
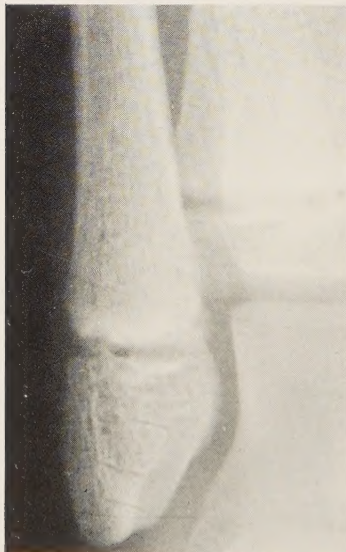


Fig. 3 Stage I - physeal fracture distal fibula.

a - AP. No obvious injury.

b - AP. 16 days after injury. Thin metaphyseal callus (arrow).



Fig. 4 Stage I - epiphyseal fracture of distal fibula (arrow).

a - AP.

b - Lateral.



Fig. 5 Stage II

a - AP. Minimal metaphyseal fragment (arrow). Medial malleolus displaced upwards and medially.

b - Lateral.

Stage II

According to Gerner-Smidt stage II.

According to Salter-Harris

distal fibula: type I, II, or III

distal tibia: type III, IV, or Z (Kärrholm et al. 1982a).

20 boys aged 6-16 years; 14 girls aged 6-14 years.

Twenty-seven cases with a stage II injury had a S-H type I injury through the distal fibular physis, four cases a S-H type II injury, one case a S-H type III injury, and two a S-H type I injury in combination with a minimal fragment at the tip of the lateral malleolus.

Twenty-seven children showed a S-H type III injury through the medial malleolus. In three of these the epiphyseal fracture ended very close to the medial part of the growth plate, limiting the transverse physeal fracture to a minimum. Seven children showed a type IV injury. In five of these the fracture ran vertically through the medial part of the epiphysis entering the growth plate, then medially through the growth plate for some mm, upwards through the medial part of the metaphysis forming a zigzag pattern. The metaphyseal fragment was small in all five cases (Fig. 5 a and b).

When displacement was found, the medial malleolus displaced upwards and medially. Sometimes the talus was tilted inwards. Twenty-four cases showed a displacement less than 2 mm, seven displacement between 2-5 mm; in three the displacement exceeded 5 mm.

Treatment: Because of displacement two children were treated with closed reduction, one with closed reduction and percutaneous pinning, and seven with open reduction and osteosynthesis. Fixation was performed with pins in six; in one in combination with a staple. In one boy, 15 years old, screw fixation of the medial malleolus was performed and the lateral malleolus was stabilized with pins.

Plaster fixation was performed 4-6 weeks in all cases with stage II injuries.

B. Closed growth plates

Stage I

9 boys aged 15-17 years; 4 girls aged 15-17 years.

One patient with a transverse fracture just beneath the insertion of the anterior talo-fibular ligament was treated with open reduction and fixation.

Stage II

4 boys aged 15-17 years; 2 girls aged 17 and 18 years.

Four were treated with open reduction. Two showed a transverse fracture of the distal fibula in combination with a vertical or slightly oblique fracture of the medial malleolus. One showed ruptures of the ligaments at the tip of the lateral malleolus in combination with a vertical fracture through the medial malleolus. The last patient had a fracture of the lateral malleolus detaching the calcaneo-fibular ligament, a rupture of the anterior talo-fibular ligament in combination with rupture of the deltoid ligament.

Plaster fixation was performed for 5-6 weeks after stage I and II injuries of adult type.

II. Age and sex distribution.

The age difference between boys and girls, and between boys and girls with different stages were evaluated with Student's t-test. The distribution of stages and sex was evaluated with χ^2 -test (Table 2).

The average age for boys with SA injuries and open growth plates was 1-2 years higher than for girls ($p < 0.05$). The average age for stage I injuries through the distal fibular physis and for stage II injuries was about two years higher for boys than for girls ($p < 0.05$), but the stage I injuries through the distal fibular epiphysis showed the same average age (about 10 years) in girls and boys. The difference of number of boys and girls with variable stages was insignificant.

TABLE 2.

	SA Stage	Salter-Harris		Sex	No. of cases	Mean age ± SD
		Fibula	Tibia			
Open growth plates	I	I,II,III	-	M	38	10.5 ⁺ 3.8
				F	31	8.7 ⁺ 3.4
	I	-	-	M	10	10.3 ⁺ 3.3
				F	15	10.5 ⁺ 3.1
	II	I,II,III	III,IV,Z	M	20	11.9 ⁺ 3.1
				F	14	9.6 ⁺ 2.5
	I-II	I,II,III,-	III,IV,Z	M	68	10.9 ⁺ 3.5
				F	60	9.6 ⁺ 3.2
Closed growth plates	I	-	-	M	9	16.1 ⁺ 0.9
				F	4	15.5 ⁺ 1.0
	II	-	-	M	4	16.8 ⁺ 1.0
				F	2	17.5 ⁺ 0.7
	I-II			M	13	16.3 ⁺ 0.9
				F	6	16.2 ⁺ 1.3

Table 2. Distribution and average ages $\pm$ SD of different stages and types of SA injuries.

DISCUSSION

The terminology of traumatological classifications of ankle fractures is confusing, as the Scandinavian terminology is not synonymous to the Anglo-american. Diaz and Tachdjian (1978) used the term supination-inversion instead of supination-adduction. According to Gerner-Smidt (1963) supination-inversion is synonymous to supination-internal rotation.

Gerner-Smidt (1963) noted the close relation between supination-adduction and supination-inversion (internal rotation) stage I injuries; rupture of the anterior talo-fibular ligament can be a component also of a supination-adduction injury. This was verified here in one case with a displaced stage II injury that in addition to a fracture through the distal fibular physis and the medial malleolus showed this injury at the operation, besides two cases of adult type.

Here, the terminology and classification of Gerner-Smidt (1963) is used, this being the only classification based on experimental investigations. Furthermore the traumatological classification of Gerner-Smidt (1963) is suitable for clinical work.

Adduction trauma to the ankle can, besides malleolar fractures, produce ligamentous lesions at the tip of the lateral malleolus (Gerner-Smidt 1963) but in this study only fractures were considered. Partly supra-malleolar adduction injuries as described by Carothers and Crenshaw (1955) and Peterson (1980), and pronation-abduction injuries (Gerner-Smidt 1963) have also a medial malleolar fracture. However, pronation-abduction will produce a more transverse fracture of the medial malleolus and in combination with a lateral injury the ankle will displace laterally; contrary to the adduction force resulting in an upward and medial displacement of the talus and the medial malleolus.

Separation through the growth plate of the distal fibula without injury to the distal tibia can be caused by supination-eversion force (Gerner-

Smidt 1963, Kleiger and Barton 1964, Kärrholm et al. 1982a)(synonyms: supination-external rotation, supination-outward rotation, supination-lateral rotation) but usually this injury is a result of supination-adduction trauma. Poland (1898) supposed that "it is exceedingly probable that the majority of examples of supposed fractures of the lower end of the fibula occurring in youth from 12-19 years of age are really separated epiphyses". He also found that the distal fibular epiphysis was one of the most readily separated epiphyses of the long bones by violent adduction or abduction. Bergenfeldt (1934) found 16 cases (5%), Gerner-Smidt (1963) 29 cases of adduction type (9-10% of all fractures), Spiegel et al (1978) 25 cases (11%). Blount (1955) and Rang (1974) regarded the S-H type I injury as the most common type as later found by Spiegel et al. (1978). In this study most stage I injuries were of S-H type I and the frequency of physeal separation through the distal fibula was higher than in the material presented by Gerner-Smidt also when related to the total number of stage I injuries with fracture (present material: 69/94, Gerner-Smidt: 29/69).

The difficulties of diagnosing S-H type I injury of distal fibula when nondisplaced have earlier been recognized (Eliason and Ferguson 1934, Cameron 1975). A small sliver-like cortical avulsion of the metaphysis (Werenskiold 1927) or epiphysis (Swischuk 1979) can be the only radiographical sign of a physeal separation. However, according to Caffey (1973), small ossicles can be situated close to the physis without any known trauma and revealed by comparison views.

This study includes cases with clinical and radiological signs of distal fibular physeal injury or, if radiological signs were initially lacking, metaphyseal callus 2-4 weeks after injury. However, probably the number of physeal separations through the distal fibula was actually higher as follow-up radiographical examination was performed only in a few cases.

The radiographical diagnosis of a fracture through the medial malleolus is easier, but a separate ossification centre at the medial malleolus is sometimes interpreted as a fracture fragment. In doubtful cases, compari-

son views are recommended. According to Harrison and Keats (1980), epiphyseal clefts appearing in the medial malleolus could be misinterpreted for a fracture, but were not found in this study and are probably rare. Furthermore, the extent of the displacement can be difficult to interpret in the younger child because of incomplete mineralization of the epiphysis.

The traumatological classification gives a hint of the complete injury; a lateral injury should be suspected when a medial malleolar fracture of supination-adduction type is present.

The frequency of SA injuries in this study was about 35% (32% with closed growth plates included), whereas supination-eversion injuries were found in 40% (39% with closed growth plates included) (Kärrholm et al. 1982a), and pronation injuries were found in 14% (18% with closed growth plates included) (Kärrholm et al. 1982b). Gerner-Smidt (1963) found 90 SA injuries with fractures and 170 with ligamentous injuries at the tip of the lateral malleolus. Twenty-one of them showed a minimal fragment at the tip of the lateral malleolus. Excluding the ligamentous injuries without any signs of bony injury and supination-inversion stage II and III injuries, not included in this material, will give a frequency of about 34-35% SA injuries with osseous lesions corresponding to 35% SA injuries found in this investigation. However, these percentages are slightly dependent on chosen age limits, and the material by Gerner-Smidt (1963) was not separated into injuries with closed and open growth plates.

In this material the mean age for girls with SA injury was lower than for boys, as earlier found among supination-eversion injuries (Kärrholm et al. 1982a). The mean age for the SA injuries was lower than for the supination-eversion (SE) injuries (Kärrholm et al. 1982a) with open growth plates ($p < 0.001$).

The stage I injury has a good prognosis; because of growth disturbance, no problems after this injury are reported. The stage II injury has a

worse prognosis, especially in the younger child, due to risk of developing a progressive varus deformity (McFarland 1931, Aitken 1936, Gill and Abbott 1941, Giuliani 1952, Mouterde et al. 1979). Moreover, secondary arthrosis because of incomplete reduction can develop after intra-articular injuries.

None of the stage I injuries was treated with reduction, the displacement being small in all injuries with open growth plates. Gerner-Smidt (1963) reported one injury with a displacement larger than 5 mm, but largely displaced physeal fractures through the distal fibula are otherwise associated with a fracture through the medial malleolus (stage II) or due to another trauma.

Anatomical reduction of stage II injuries is recommended in the literature (Spiegel et al. 1978, Mouterde et al. 1979, Ogden 1981). Mouterde et al. (1979) and Ogden (1981) recommend exact reduction to reduce the risk of growth disturbance, whereas Spiegel et al. (1978) stressed the importance of restoring joint congruity and concluded that anatomical reduction could probably not improve the prognosis for growth of the damaged growth plate and as did earlier Bisgard (1938) and Rang (1969) aware of the risk to cause further damage to the growth cartilage by open reduction.

This study had two stage II injuries treated with closed reduction and one with closed reduction and percutaneous pinning. In another case, closed reduction was unsuccessful and was followed by open reduction. Six cases were primarily treated with open reduction. Of those, five have been followed 2-6 years after injury; one with a remaining displacement of about 2 mm after open reduction has developed a slight varus deformity besides one with a shortening. Two of those treated with closed reduction have developed a varus deformity; both needed surgical correction of the deformity. In one, the residual displacement after reduction was 2-3 mm; the other showed no or only slight remaining displacement. Besides this, one case of varus deformity (not included in this study) developed arthrosis of the ankle joint radiographically verified 24 years after trauma (unpublished data).

Spiegel and Mast (1980) recommend fixation with screw transversely through the epiphysis to obtain a better lag effect. However, in the younger child with a small epiphysis, it usually suffices to use pin fixation transversely through the epiphysis, and where there is a large metaphyseal fragment, through the metaphysis.

There are several reports of bad results after treatment of SA injuries; early diagnosis, adequate treatment concerning the growth plates and the joint congruity, and awareness of problems such as growth retardation or growth arrest is crucial if the frequency of secondary procedures should be minimized and the risk of secondary arthrosis be avoided. Despite adequate treatment, there is a risk of growth deformity because of damage to the growing cartilage close to and within the fractured region. These patients should be followed radiographically 1-2 years after injury as judged from growth analysis using a roentgenstereophotogrammetric technique (Kärrholm et al. 1982c).

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